# Book Reviews

## Practical Handbook of Material Flow Analysis

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Since the publication of *Metabolism of the Anthroposphere* in 1991, the concept of a company, city, or region functioning as a living organism with metabolic processes – an anthroposphere – has become more and more accepted in science, engineering, and material management. Unfortunately, a widely accepted methodology for applying these concepts to management of resources, wastes or environment, for example, has been lacking to date. But now the time of waiting is over – thanks to Paul H. Brunner and Helmut Rechberger and their 'Practical Handbook of Material Flow Analysis (MFA)'.

Both authors have developed and experienced MFA by profession. For nine years Prof. Paul H. Brunner was Senior Lecturer at the Swiss Federal Institute of Technology (ETH) Zurich, where he and Prof. Peter Baccini published the pioneering book *Metabolism of the Anthroposphere*. Since 1991, he has been Professor of Waste Management at the Vienna University of Technology, where he is now Head of the Institute for Water Quality and Waste Management (IWA). Prof. Helmut Rechberger started as a doctoral student at the IWA and, after a post-doc fellowship at Yale University and senior lectureship at the Chair of Resource and Waste Management (Prof. Peter Baccini) at the same ETH Zurich, returned in 2003 to the Vienna University of Technology, where he now holds the Chair of Resources Management at IWA.

The Practical Handbook of Material Flow Analysis is directed towards engineers active in the fields of management of resources, environment and waste, working in private companies, as consultants, in government authorities or educational institutions. The book establishes a stringent, transparent and serviceable methodology for investigating the material metabolism of anthropogenic systems. Only four sentences are required to describe the principles of the methodology of MFA and its main application fields:

*Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material. Because of the law of the conservation of matter, the results of an MFA can be controlled by a simple material balance comparing all inputs, stocks, and outputs of processes. It is this distinct characteristic of MFA that makes the method attractive as a decision-support tool in resource management, waste management, and environmental management.*

To make MFA generally understandable for a broad readership and to enrich the information background of LCA experts at the same time, is a brilliant feat and the authors' real reward. Written in a very clear and precise language, making the ambitious matter comprehensible, the book has an excellent didactic structure and continues to offer further food for thought. Tables and figures are very clear and informative, and most of the figures are furnished with detailed explanations and comments, which make them easy to understand. At the end of relevant sections, related problems allow the reader to exercise newly acquired knowledge, to learn applications of MFA and to gain more experience. These sample problems are very challenging in part, not only for students, but for professionals as well. On the other hand, it is very instructive to apply MFA to these problems, because this is the only way to check one's comprehension of the methodology. Many of these sample problems are of high ecological and political concern, such as, for instance: *Assume that P in detergents for textiles is phased out. Is this measure sufficient to prevent eutrophication (limit for eutrophication = 0.03 mg/l) of the lake?* The solutions are available for download at the IWA website, but the URL given is unfortunately not correct, the right address is http://www.iwa.tuwien.ac.at/MFA-Handbook/solutions.pdf.

The book contains four chapters:

1. Introduction (33 pages)
2. Methodology of MFA (132 pages)
3. Case studies (134 pages)
4. Outlook: Where to go (10 pages).

In **Chapter 1**, the book briefly presents a short overview (*What is MFA?*) about basic concepts, terms and definitions of MFA. In the following, the diverting, but nevertheless profound survey about the history of MFA draws a bow from the basic principle of any MFA – the conservation of matter – first postulated by Greek philosophers, to Nobel Prize winner Wassily W. Leontief (1906–1999) and his economic input-output methodology. Starting in the sixties, analyses of city metabolism like those for a theoretical American city (Wolman 1965), for Brussels (Duvigneaud and Denayeyer-DeSmet 1975) or Hong Kong (Newcombe et al. 1978), and regional material balances like automobile-emitted lead in Los Angeles (Huntzicker et al. 1975) are discussed as early material flow analyses. In the early nineties, Baccini, Brunner and Bader extended MFA to metabolic processes in man-made systems (*Metabolism of the Anthroposphere*) and applied these methods for improvement of resource utilization and environmental protection on a regional level. Further studies on metabolic processes of regions, nations or even globally, also based on MFA, are shortly discussed here, inter alia *Colonization* (Fischer-Kowalsky et al. 1997), *Factor 4* (von Weizsäcker 1997), *Factor 10* (Schmidt-Bleeck 1997), *Conaccount* (Bringezu et al. 1998), *Ecological Footprint* (Wackernagel et al. 1999) and *The Weight of Nations* (Matthews et al. 2000). The authors show different applications, like inter alia MFA as a tool for providing transparency in environmental impact statements, for controlling pathways for material use and industrial processes, for balancing industrial input and output to natural ecosystems, as a first step of every LCA, and as a tool for the identification of key issues of anthropogenic metabolism. Finally, MFA allows early recognition of potentially harmful or beneficial accumulations and depletions of stocks and a timely prediction of future environmental loadings. This is basic knowledge for setting priorities regarding measures for resource conservation, environmental protection and waste management.

**Chapter 2** comprehensively explains the terms, definitions and especially procedures of MFA in a kind of thoroughness, which can hardly be found elsewhere. In addition – and what makes this book highly valuable for the readership –, this chapter discusses three software tools suited for MFA: Microsoft EXCEL®, UMBERTO®[1], and GaBi® 4[2]. The excellent and very user-friendly chapter 2.4 Software for MFA is written by Oliver Cencic, an expert who is

[1] by IFEU, Heidelberg

[2] by the Institute for Polymer Testing and Polymer Science (IKP) at the University of Stuttgart in cooperation with PE Europe GmbH, Leinfelden-Echterdingen


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additionally author of the most challenging chapter 2.3 Data uncertainties – which, I must confess, I skipped. The three software tools were selected because they were well established, were available in English, were (except EXCEL, which is part of the popular Microsoft Office® package) available as a test or evaluation version (GaBi for free, Umberto for 300 Euro), were well supported and maintained, and were based on different calculation models. The potential uses and limitations of these software tools are compared by a case study on PVC: *... only EXCEL can be trimmed by users (programming experience is of advantage) to fit the requirements of MFA. Because none of the tested software products was developed specifically for MFA, none of them is the perfect choice. GaBi and UMBERTO can be used to perform MFA, but they are much better suited for LCA. EXCEL is the most flexible tool of all ...*

The results of an MFA have to be evaluated. The authors discuss several evaluation methods like MIPS (material intensity per service unit) by Schmidt-Bleek, Sustainable Process Index (SPI) by Narodoslawsky and Krotschek, Swiss Ecopoints (SEP), Exergy, Cost-Benefit Analysis (CBA), Anthropogenic vs. Geogenic flow (A/G) and Statistical Entropy Analysis (SEA) by Rechberger. *In most cases, none of them can be considered complete and sufficient for a comprehensive assessment. On the other hand, most of the introduced methods are constantly undergoing further development regarding standardization, reliability, and completeness.*

Chapter 3 is the most interesting chapter of all. It consists of fourteen proven, application-oriented MFA case studies, by which the authors describe the implementation of MFA methodology (procedure and results) to selected anthropospheres, exemplifying the potential of MFA to contribute to sustainable material management:

**Environmental Management**

**Case study 1: Regional lead pollution (Bunz Valley 1987):**
*... if the regional flows of lead remain the same for the next 100 years, the stock* (= accumulation in the region) *will have increased from 1,000 to 7,000 t! ... Without the present study, this buildup of lead occurs unnoticed.*

**Case study 2: Regional phosphorus management (Bunz Valley 1987)**
*Taking into account the current amount of P in the soil (≈10,000 t) and the annual accumulation of 68 t/year, it can be assessed that the P concentration in soils will be doubled in about one and a half centuries, if present agricultural practice is maintained. ...*

**Case study 3: Nutrient Pollution in Large Watersheds (Danube Countries 1997)**
*If no actions are taken, the capacity of the River Danube, the delta, and the 'final sink' black Sea will be overloaded, with serious ecological and economic consequences. It is not the 'classical' resource problem (lack of nutrients) that will limit the development of the region. Rather, it will be the lack of appropriate sinks that restricts progress. Strategies to limit nutrient loads need to be discussed and developed.*

**Case study 4:MFA as support tool for Environmental Impact Assessment (EIA) (SYSTOK 1995)**
*The case study shows that the power generation based on coal is relevant for enhanced flows of arsenic, selenium, mercury, sulfur, and carbon within the region's metabolism. The landfill represents a considerable reservoir for certain metals within the region. ... Solutions have to be developed for the future, when the power plant is not in operation anymore and when funds are no longer available for landfill aftercare. ... Generally, the study shows that the power plant actually does not pose a severe burden to the region's environment. The operators use these results for their environmental impact statement and for communication with concerned local people.*

**Resource Conservation**

**Case study 5: Nutrient Management (Baccini and Brunner 1991)**
*If all MSW were turned into compost, the contribution to agriculture would only be 1 to 2%. The fraction of nutrients in wastewater from households is about ten times larger. Thus, priority in nutrient recycling should be on wastewater and not on solid waste.*

**Case study 6: Copper Management**
*It is confirmed that the stock of copper currently in use has the potential for a future secondary resource. ... Provided that waste management is adapted to recycle and treat the large amounts of residues resulting from the aging stock, copper can be managed on a nearly sustainable way.*

**Case study 7: Construction Wastes Management (and the 'Hole' problem) (Vienna 1999)**
*The results of the MFA of the two plants support the strategy of selective deconstruction. Neither of the two processes is able to accumulate or deplete significantly (factor 10) hazardous materials in any of the resulting fractions. Once again, it becomes evident that at today's stage of development, mechanical processes are of limited use for the chemical separation of waste materials. ... For optimum resource conservation, it is important to separately recover materials during the deconstruction process and to recycle uniform fractions ... individually.*

**Case study 8: Plastic Waste Management**
*The benefit of an MFA approach in resource management as discussed in this case study is as follows: a total plastic balance on a countrywide level shows the important flows and stocks of plastics and helps in setting the right priorities in resource management. First, the large and useful stock of plastics (and thus energy) in consumption and landfills is recognized. Second, potential hazards due to toxic constituents of plastic materials are identified in both stocks 'consumption' and 'landfill'; the toxics will have to be treated with care in the future.*

**Waste Management**

**Case study 9:** Use of MFA for waste analysis: Market Analysis

**Case study 10:** Use of MFA for waste analysis: Analysis of products of waste treatment

**Case study 11:** MFA to support Decisions in Waste Management: ASTRA (Evaluation of different scenarios for waste treatment in Austria)

**Case study 12:** MFA to support Decisions in Waste Management: PRIZMA (Positive list for utilizing of residues in the cement industry)

**Case study 13:** MFA to support Decisions in Waste Management: Recycling of Cadmium by MSW Incineration

**Regional Materials Management**

**Case study 14:** Regional lead management (Bunz Valley 1987):
*In order to concentrate lead as much as possible, the shredder residues should be treated in an incinerator with advanced air-pollution control. ... The region could offer to take back filter residues from MSW incineration ...*

Though all case studies are well suited to exemplify the potential of MFA to contribute to sustainable material management, I felt a little bit disappointed because one of the – to me – most interesting projects is only mentioned in the references: the study of urban metabolism of the City of Vienna (1997) regarding carbon, nitrogen and lead (chapter 2, ref. 129), while the Bunz valley project, which is ten years older, serves as a case study three times.

The final chapter, **chapter 4**, discusses the outlook: *Where to go?* Here, the authors think about the future use of MFA as a tool for resource-orientated design of products and processes, systems and restructuring the metabolism of the anthroposphere. One of the author's visions is, that ore mining will be superseded by *urban mining*, the recovery of secondary resources from the urban stock itself. Finally, MFA will turn out as one basic tool for realizing sustainable development: *New concepts are wanted to show how to improve the quality of life by consuming less energy and fewer resources. Eventually, the focus is shifted from material growth to nonmaterial welfare and development. MFA is a necessary element for such a change in paradigms. Nevertheless, it is only a tool and not a driving force. It is up to the user to apply MFA in a beneficial way.*

MFA is a valuable tool for many users. Researchers and practitioners in science, industry, consulting and government, and professionals like LCA experts or resource-oriented engineers, as well as students, will benefit from this excellent book. In conclusion, it meets the claim of serving as a **practical handbook** of Material Flow Analysis in every respect and is highly recommended to those working in the field of LCA, environmental management and engineering, industrial ecology and resource or waste management. It is benchmark-setting and should not be missing in any library specialized on sustainable development.